

Engineering the Ideal Array



Mark Rosker
Microsystem Technology Symposium
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RF Arrays in Military Systems



THAAD



XBR



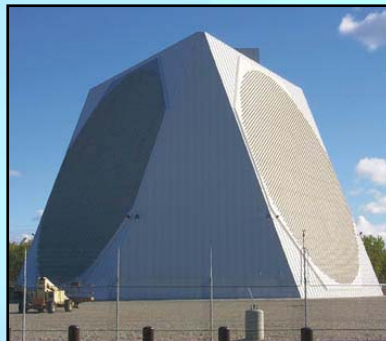
AN/MPQ Sentinel



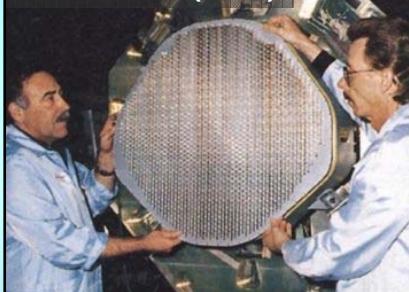
JLENS



AN/SPY-1D
(USS Mason)



AN/APG-77 (F-22)



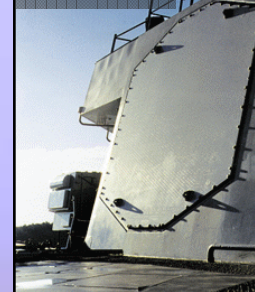
AN/SPY-1D



AN/APG-73
(F/A-18)



AN/SPY-1



AN/TPQ-37



AN/APG-81 (JSF)



JSTARS



MILCOM



Arrays are the heart of sensor systems for many military platforms

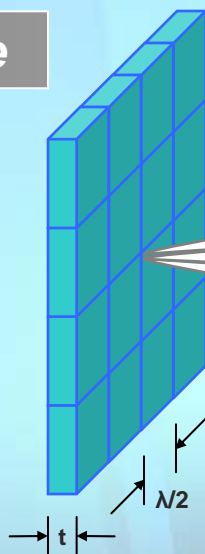


Ideal Array: The Vision



Architecture

- Scalable
- Reconfigurable
- Embedded thermal management
- Negligible mass
- Wafer-thin
- Dirt cheap



Transmit

- Huge transmit power available
- Enormous bandwidth
- Near-unity power added efficiency

Beamsteering

- Precise phase & amplitude control of each element
- Near-instantaneous speed
- Suppressed sidebands

Receive

- Near-zero noise figure
- Enormous dynamic range
- Minimal power dissipation

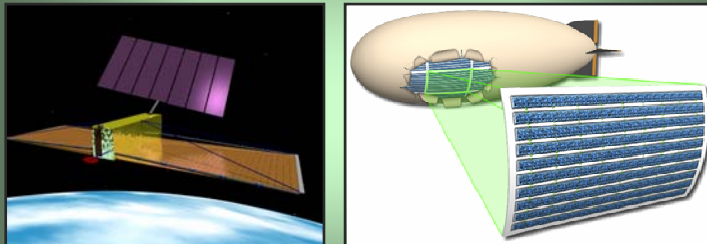
All we need now is a bit of technology...



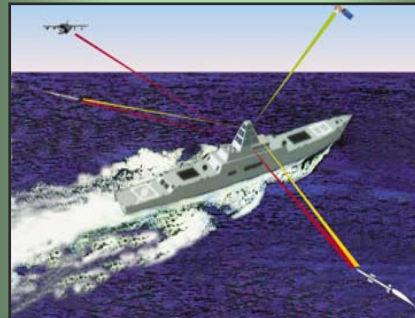
What Does it Enable?



Massive Sensor Arrays



Multi-function Systems



Conformal Sensors



Frequency Agile Sensors



Greater Range



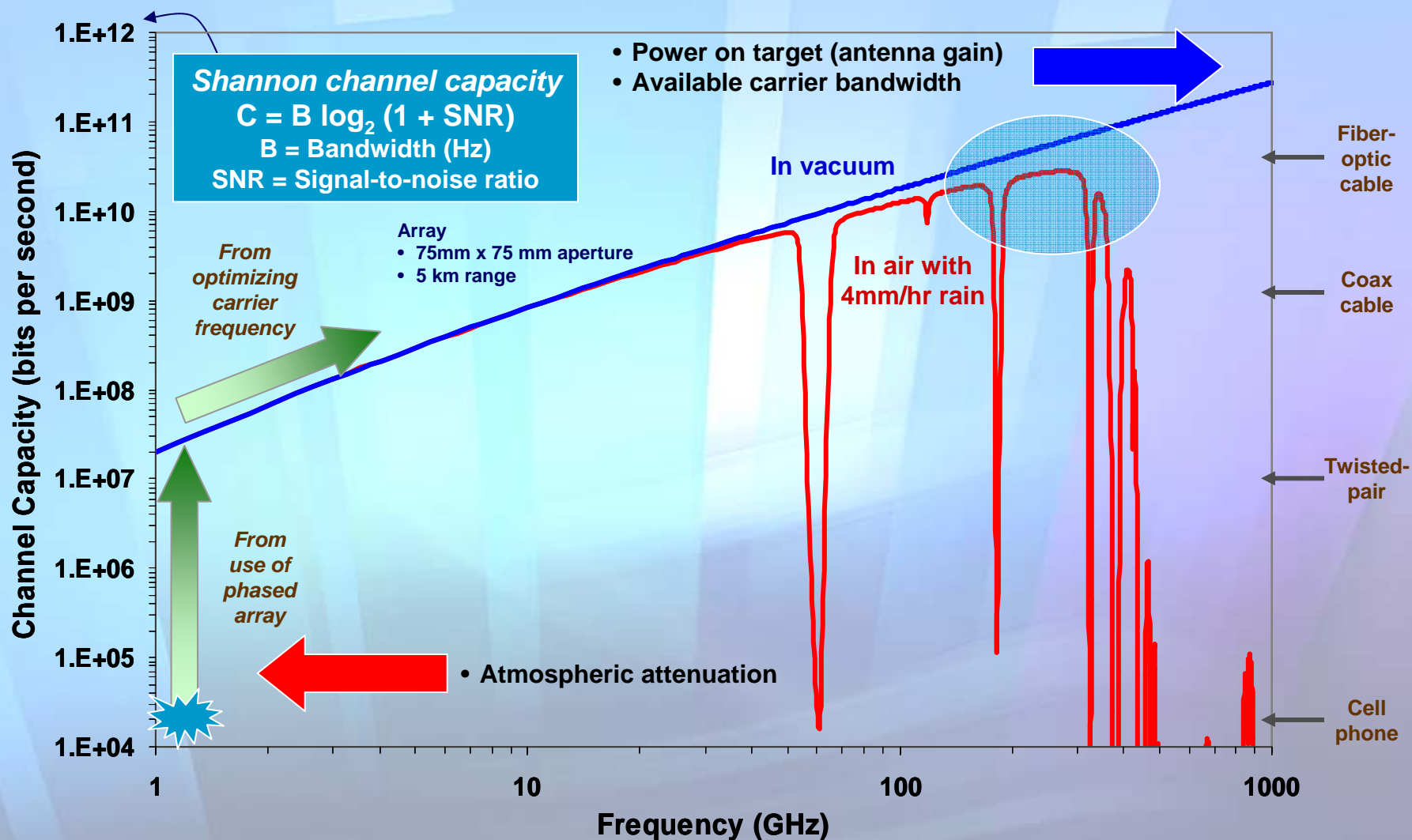
Reduced System Size



Compact, robust, intelligent sensor and communications systems



The Ideal Array and Frequency



For many applications, the ideal array is a millimeter-wave array



Arrays in Military Systems



THAAD



XBR



AN/MPO Sentinel



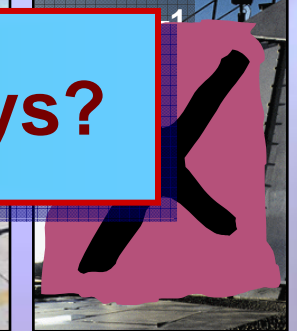
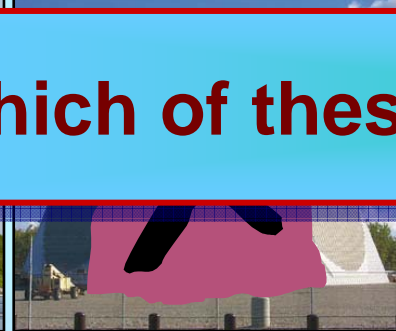
JLENS



AN/SP



Which of these are millimeter-wave arrays?



AN/TPO-37



AN/APG-81 (JSE)



JSTARS



MILCOM



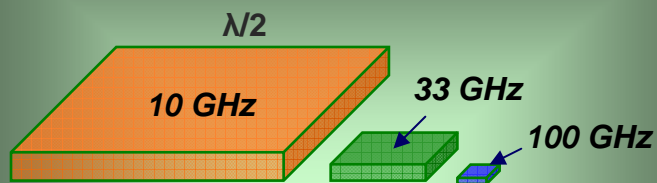
Arrays are the heart of sensor systems for many military platforms



The High Frequency Array

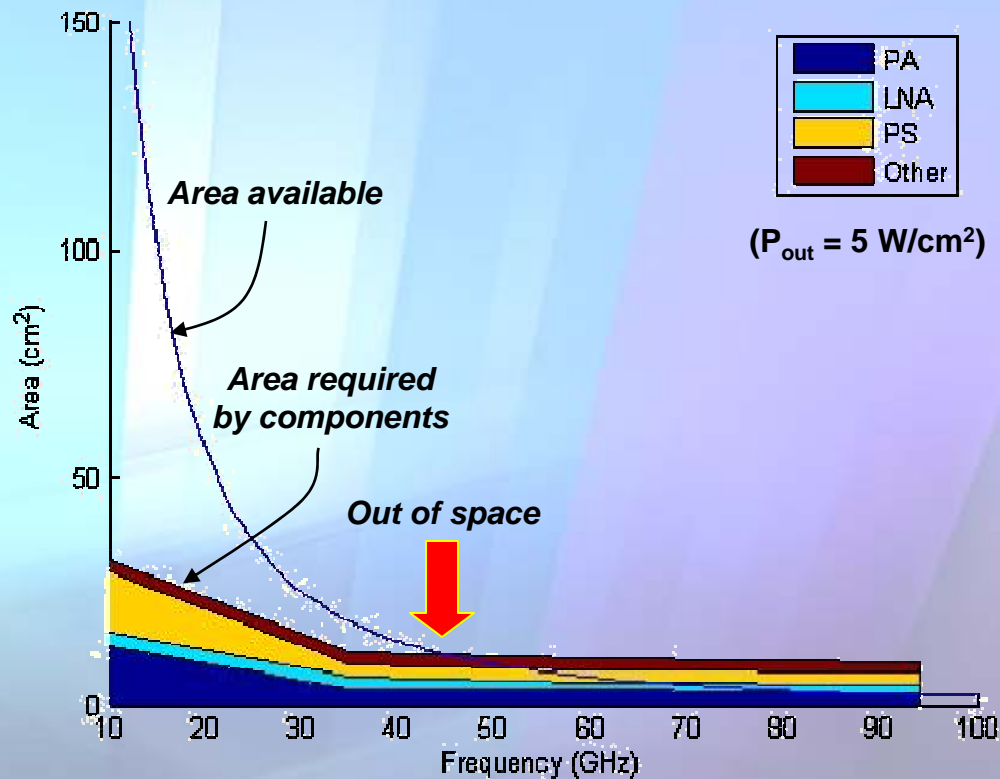


Area of an array cell scales like f^2



Each cell must still contain...

- LNA
- Power amp
- Filtering
- Diplexer/ circulator
- Phase shifting
- Limiter
- Digital control
- ...



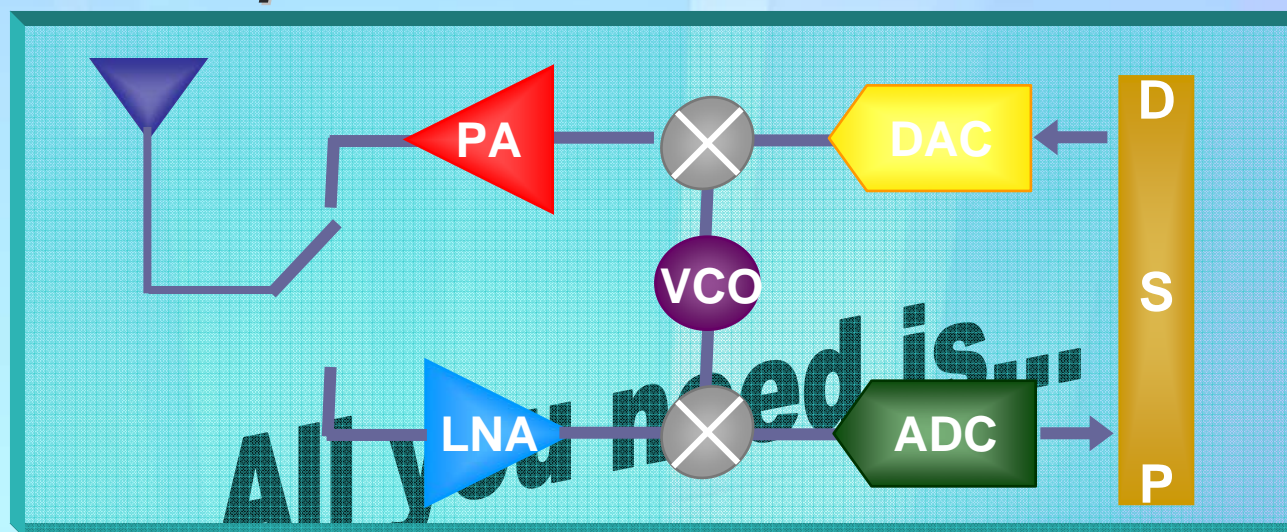
3D is only way to cram functionality into increasingly smaller pitch



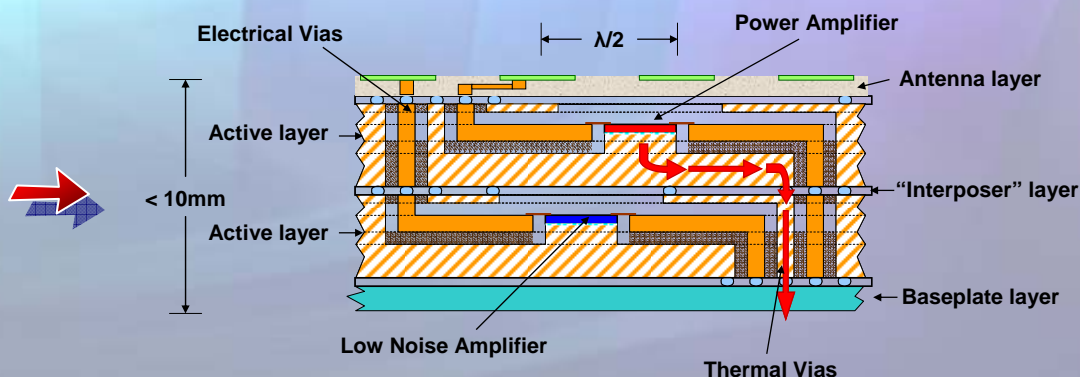
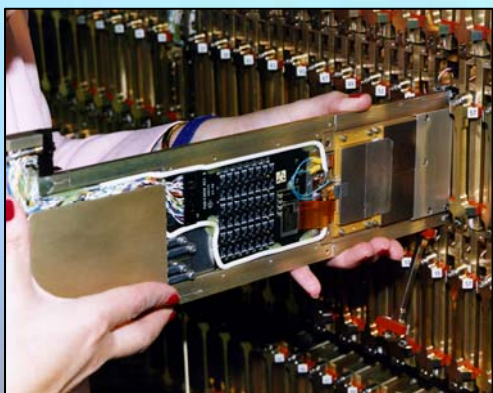
Challenges for an Ideal Array



Ideal circuit components



Ideal integration methods

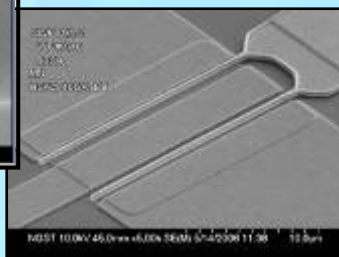
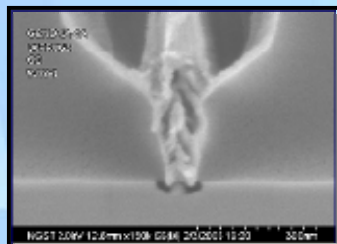




The High Frequency Integrated Circuit

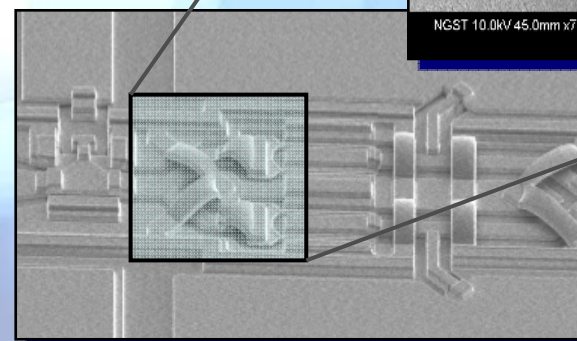
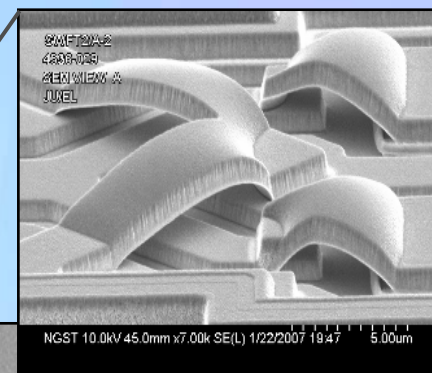
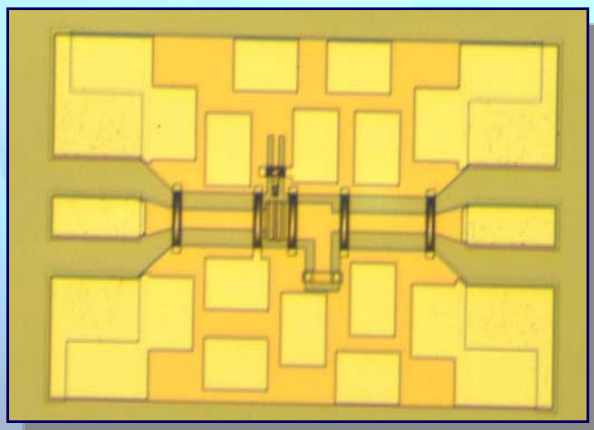


**35nm gate InP HEMT transistor
with record $G_m = 2300\text{mS/mm}$**



**S-MMIC process
development**

**347 GHz Integrated Circuit:
World's First "s-MMIC"**

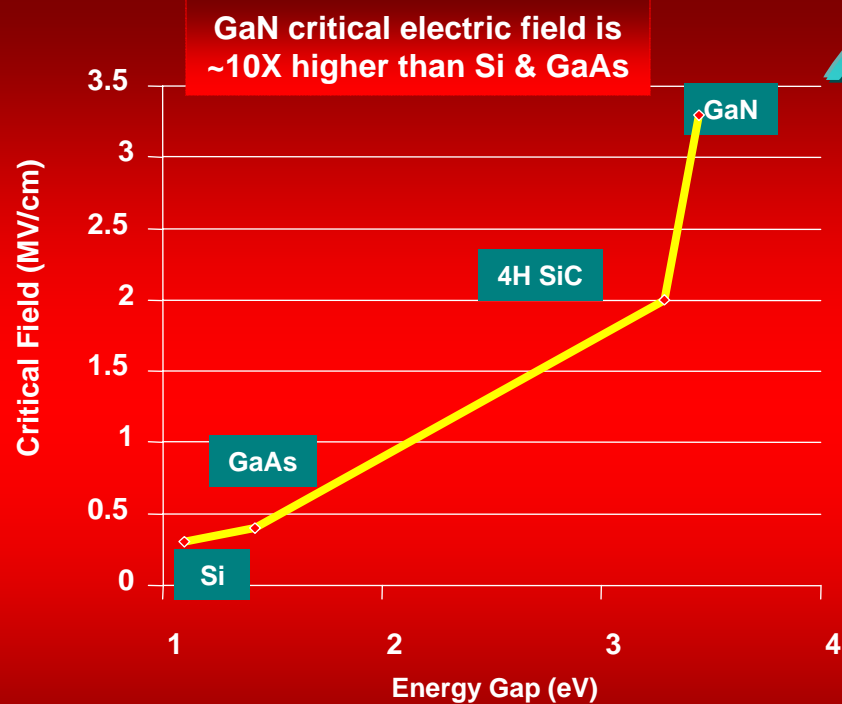


NORTHROP GRUMMAN
Space Technology

THz frequency integrated circuits are becoming a reality



Wide Bandgap Semiconductors

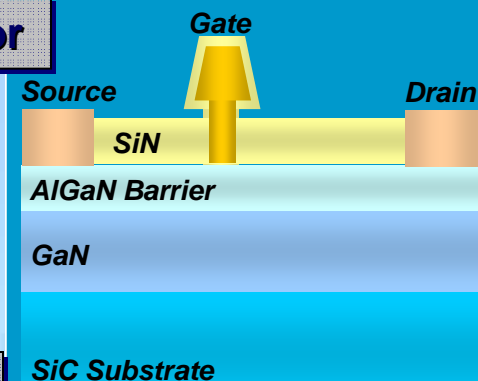


For high voltage operation for analog and RF components, $P_{\max} \propto E_g^4$

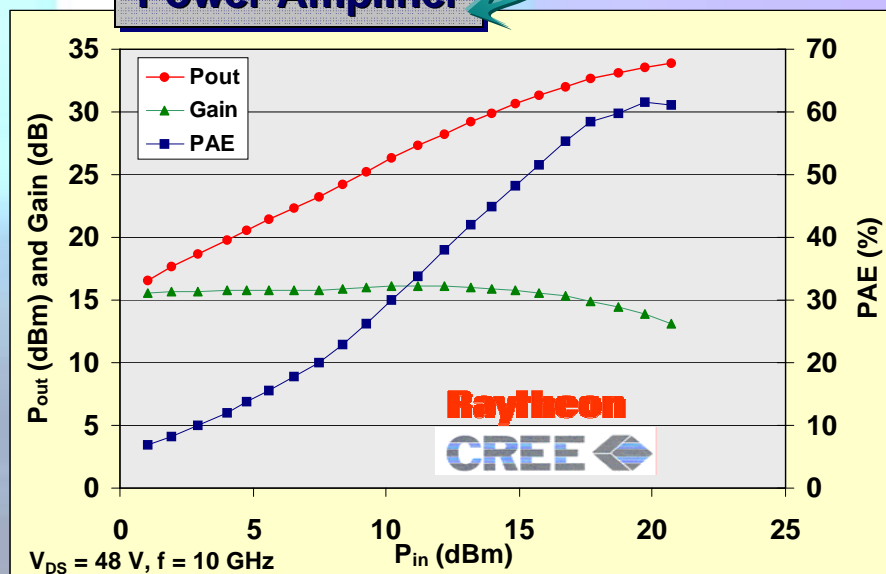
GaN HEMT Transistor

Dramatically higher:

- Output power
- Efficiency
- Bandwidth



GaN HEMT Power Amplifier



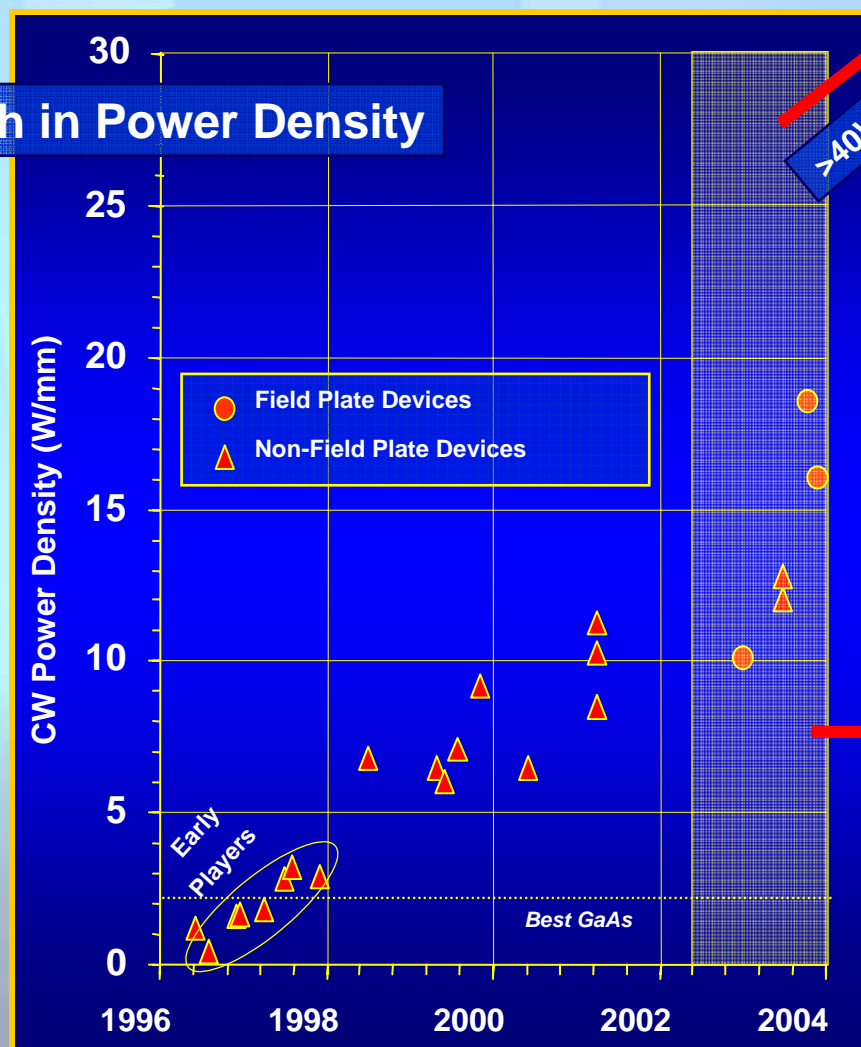
The ideal array demands the ideal power amplifier transistor material!



GaN & Power Density



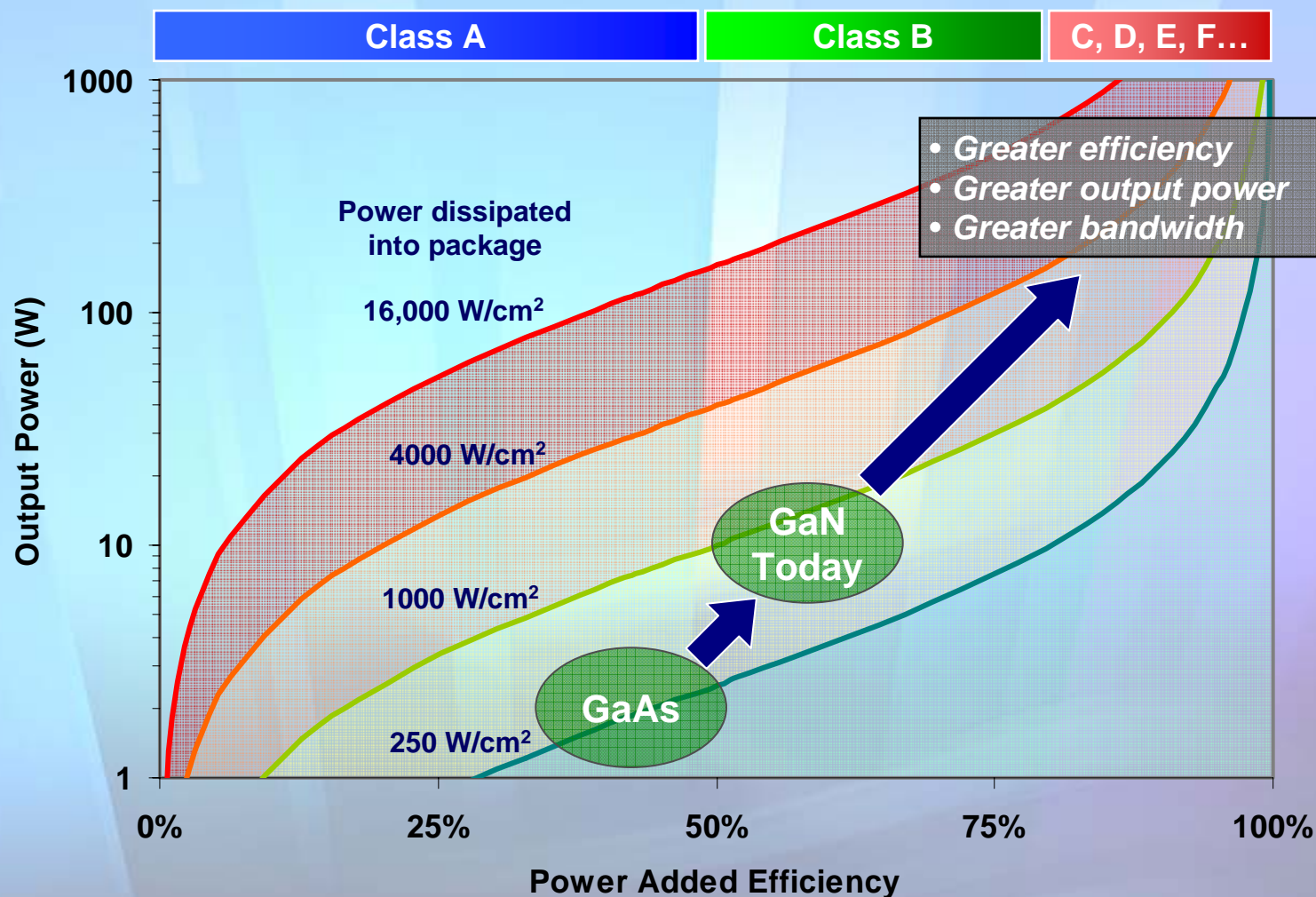
A Breakthrough in Power Density



For large GaN devices, we are still a long way from the material limit



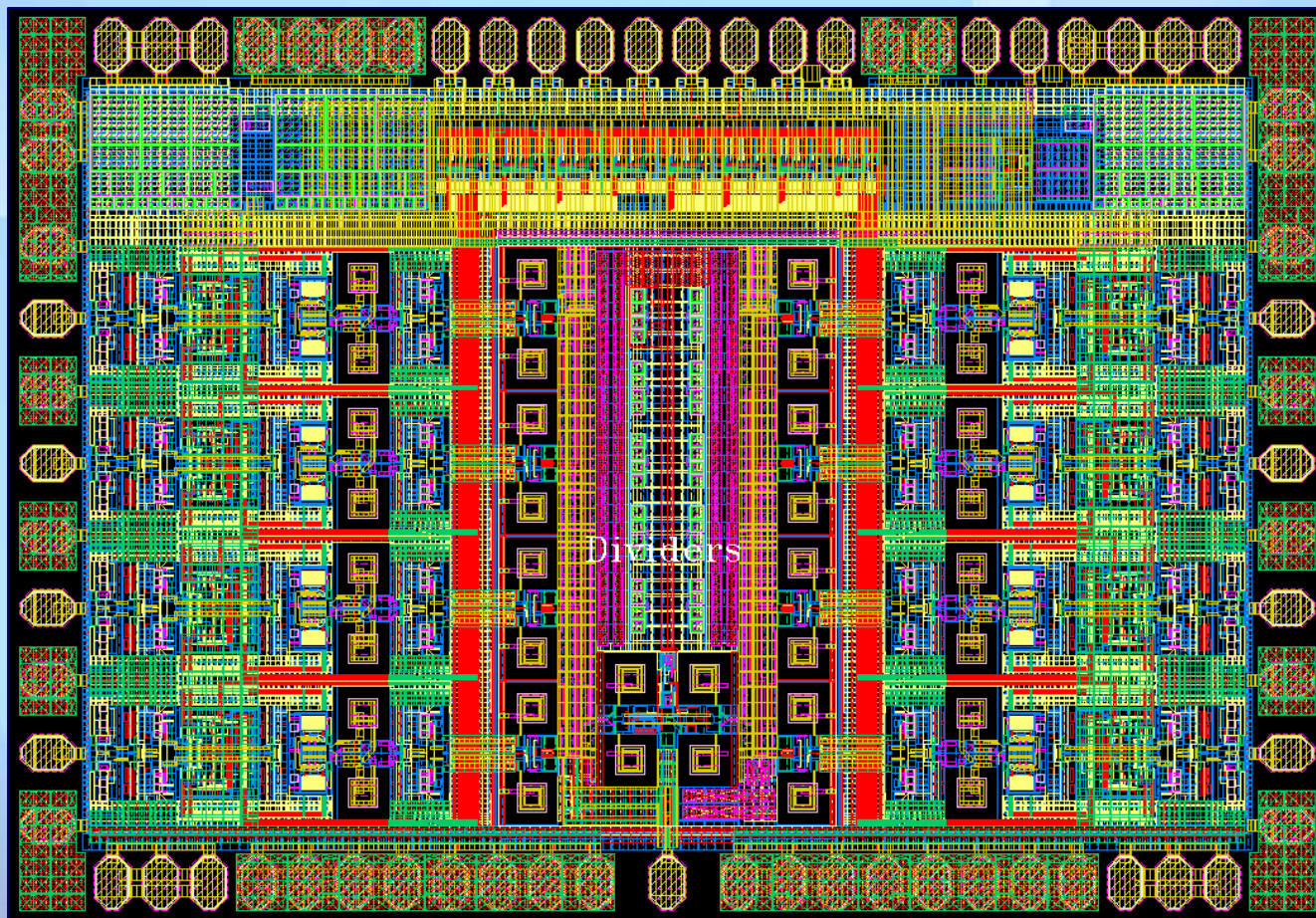
The Ideal Power Amplifier



The ideal PA demands a new focus on thermal management



Complete Beamformer-on-a-Chip



- 44GHz
- 8 channels
- All beamforming functions
 - RF amplifiers
 - 4-bit phase shifters
 - Amplitude controllers
 - Summing network
 - Power control
 - Latches for phase state
 - Address decoders
 - Digital-to-analog converters

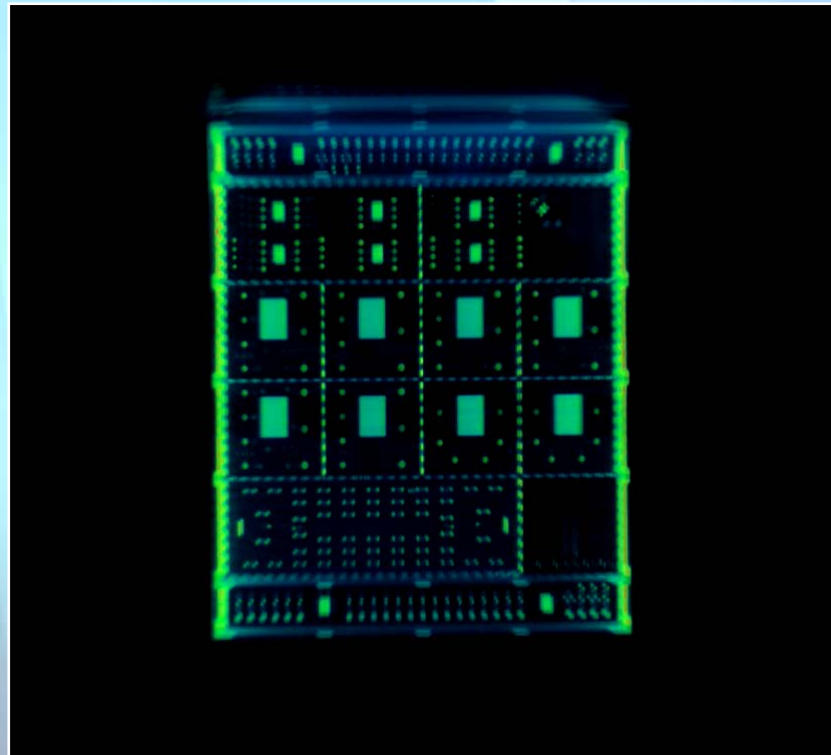
→ 2.2x2.4 mm ←

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3D Integration of an RF Array

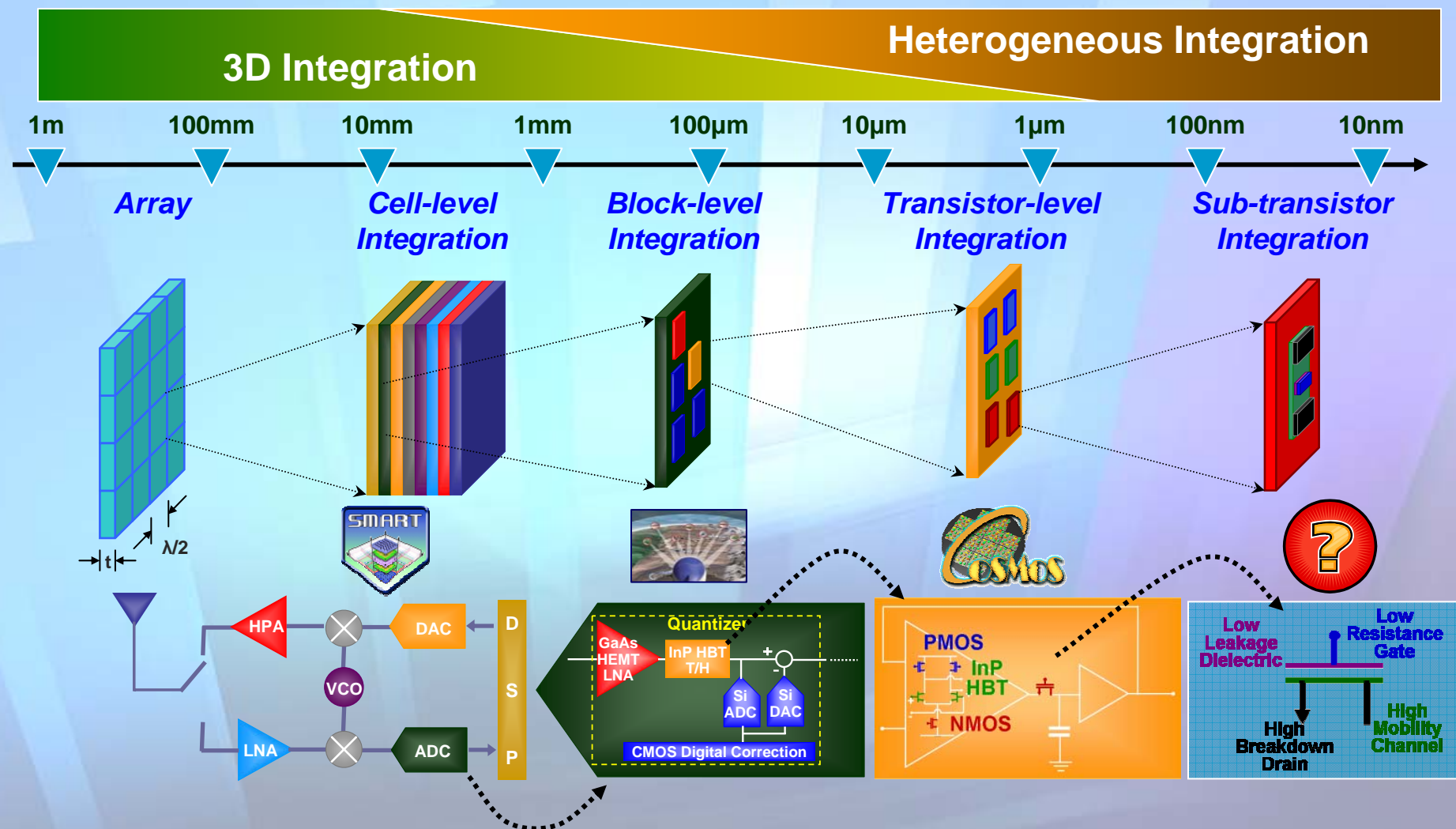


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Space Technology

Today: integrated circuits; Tomorrow: integrated arrays



Constructing the Ideal Array





The Challenge



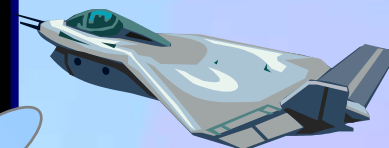
Range



Integrated

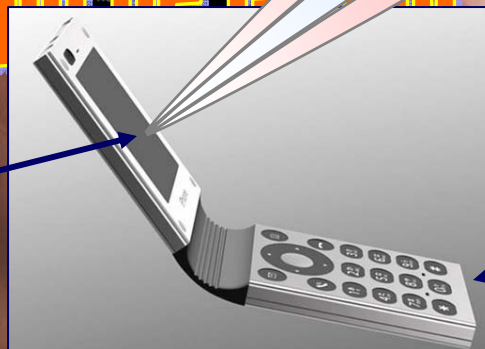
Massive capacity
($>$ coax cable)

Highly directional;
low probability of
intercept



What could be even better than this?

Array no larger
than display



Highly
efficient

Your 200GHz MTO-Phone...

...made possible by DARPA & the ideal array